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ORIGINAL RESEARCH

RELATIVE JOINT CONTRIBUTION TO JOINT HYPERMOBILITY IN RUGBY PLAYERS, NETBALLERS AND DANCERS: THE NEED FOR CAREFUL CONSIDERATION OF LUMBAR FLEXION

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ABSTRACT

Background: Generalized joint hypermobility is commonly measured using the Beighton and Horan Joint Mobility Index which provides a Beighton score of 0-9. Generally, scores of ≥4 are classified as hypermobile however joint hypermobility classification lacks consistency across the literature.

Purpose: The aim of the study was to compare the relative contribution of five joints to joint hypermobility scores in female and male rugby players, female netball players, female dancers and male and female age matched controls.

Study Design: Individual cohort study.

Methods: Joint hypermobility was assessed in 286 subjects using the Beighton and Horan Joint Mobility Index. Subjects were assigned a Beighton score of 0-9. These scores were then categorized using three different joint hypermobility classification systems and results were analyzed using a Pearsons Chi Square (x^2) to report the relative contributions of each joint to hypermobility scores.

Results: Significant differences existed for group and gender analysis at the left and right 5th metacarpophalangeal joints, left and right thumb, left and right elbow and lumbar spine ($p < 0.001$). Lumbar flexion demonstrated significant x^2 values and large effect sizes for all groups. This effect size was reduced to a moderate effect size when male against female analysis was performed and joint hypermobility was greater in females in comparison to males. The knee joint demonstrated the lowest hypermobility across all populations and ranged from 3% in male rugby players to 24% in female dancers. Seven hypermobile knees existed in males and 53 in females. Female dancers had the highest prevalence (93%) of hypermobile lumbar flexion and all female groups had a higher prevalence of hypermobile lumbar flexion than males. The removal of lumbar flexion from the total Beighton score had no effect on joint hypermobility prevalence in males in contrast to females where changes were demonstrated.

Conclusion: Joint hypermobility classification of female dancers should consider the high prevalence of hypermobility of lumbar flexion in interpretation. The consideration of separate classification systems for males and females, and between athletes of different sports and dancers may aid future understanding.

Levels of Evidence: 2b

Key words: Beighton score, female dancers, hypermobility, lumbar flexion.

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Conflict of interest
No conflicts of interest are reported.

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INTRODUCTION

Joint hypermobility (JH) is excessive end of range joint motion in one or multiple joints.[1] The original JH assessment[2] was modified further by Beighton and Colleagues.[3,4] The Beighton and Horan Joint Mobility Index (BHJMI) assesses joint range of motion (ROM) at the 5th metacarpophalangeal joints, thumbs, elbows, knees and lumbar spine which provides a Beighton score (BS) of 0 to 9. JH scores of ≥4 are classified as "hypermobile"[5] however values of four, five and six have been utilized to classify JH.[6]

JH is more prevalent in females than males[7] with rates of 24% in male rugby players,[8] 26.2% in students,[9] 63% in female netballers[10] and 66% in dance students.[11] BHJMI interpretation may need to be sport or activity specific due to this varying prevalence. Within the JH literature there has been limited discussion regarding the relative joint contribution to JH and the potential implications this may have in terms of injury prevention and performance. The development of an enhanced understanding of joint contribution and reference values within varied populations may enhance management of individual athletes. JH may have performance benefits within dance.[12] The exclusion of lumbar flexion from the criteria of JH diagnosis in dancers[13,14] has been utilized due to the large lumbar flexion ROM required for dance performance however this has not been applied consistently in further studies. In netball, potential performance benefits may exist at the 5th metacarpophalangeal joint which has been reported to demonstrate the lowest JH of the BJHMI (15% of netballers had hyperxtensibility of the 5th metacarpophalangeal joint).[10] This may represent associated finger flexion conditioning[10] and relate to increased neuromuscular tone which limits passive joint range.[15] In netball, impaired movement control has been reported in individuals with general joint hypermobility.[10] A relationship between performance benefits and JH has not been previously reported in rugby.

In dance, JH is associated with increased injury risk with both low BS (0-2) and high BS (5-9) dancers, who were 1.43 and 1.22 times more likely, respectively, to suffer injury than dancers in the medium BS group (3-4).[16] JH has been associated with an increased risk of injury in netball, with 21% of netballers with a BS of 0-2 having sustained previous injury compared to 37% (BS 3-4) and 43% (BS 5-9).[17] In rugby players with a BS 4-6, injury incidence (116.7 injuries/1000 hours) was significantly higher than those with a BS of 0-3 (43.6 injuries/1000 hours).[8] There has been no focus on joint contribution in previous studies[8] and due to the contact nature of rugby, JH may be a risk factor for injury[17] and there is a potential need for enhanced understanding of JH to reduce the potential risk of injuries such as dislocation and subluxation. Different JH classification systems have been utilized and therefore to aid interpretation of joint contribution the current study used three JH classification systems.[4,8,18]

Recurrent musculoskeletal pain can be a manifestation of JH and may predispose an athlete to trauma.[19] Asymmetrical joint surface loading contributes to joint surface wear and the joint may progress from being "*loose*" to "*loose and painful*".[20] Pain may originate from joint stretch receptors and swelling of the joint lining and can often be the first sign that JH problems may exist[20] which therefore may act as a warning sign to clinicians to monitor the individual carefully to potentially reduce injury risk.

The aim of the study was to compare the relative contribution of five joints to joint hypermobility scores in female and male rugby players, female netball players, female dancers and male and female age matched controls.

METHODS

Participants

Two hundred and eighty-six subjects volunteered to participate in this study including 65 female rugby players (FR), 38 male rugby players (MR), 61 netball players (NP), 42 female dancers (FD), 40 aged matched male subjects (MS) and 40 aged matched female subjects (FS). Recruitment was aimed at attaining age-matched groups and the sport and dance groups were standardized for weekly participation levels. Female and male controls were recruited by asking for volunteers via a poster campaign within the university. All subjects were 18 years of age or older and were excluded from the study if they had suffered an injury in the previous

30 days[21] which prevented training, match or dance class participation. Subjects completed a medical screening questionnaire prior to participating in the study and additional exclusion criteria included heart disease and pregnancy. Participation was voluntary and subjects were provided with information sheets and completed informed consent forms prior to participation. The University Research Ethics Committee provided ethical approval (SPA-REC-2015-185) in accordance with the Helsinki declaration.

Procedures

All testing was conducted indoors under the supervision of the same researcher and prior to testing the subjects' height (cm) was measured using a stadiometer (Leicester Height Measure, Child Growth Foundation) and body mass (kg) were recorded using digital scales (Salter 9028, Kent, UK). The subjects date of birth and ethnicity was recorded and participation in other sports and dance was determined prior to testing to ensure that subjects did not cross participate in the observed genres.

JH screening

Testing was conducted prior to training or dance classes to prevent any potential effects of exercise on JH and subjects did not participate in exercise for a least 12 hours prior to testing due the potential effects of warm up on joint ROM.[22] The BS[4] was used to measure JH and has an Intraclass Correlation Coefficient (ICC) of 0.91 and a kappa 0.74.[23] The same clinician performed the assessment, specifically a Chartered Physiotherapist with 15 years' experience in BS classification by measuring ROM of the 5th metacarpophalangeal joints (1 point each joint), thumbs (1 point each joint), elbows (1 point each joint), knees (1 point each joint) and lumbar spine (1 point) which provided a maximum score of 9. A goniometer (Vivomed, UK) was used to measure all joints except the lumbar spine for which JH was classified as yes/no based on the participants ability to put the palms of their hands flat on the floor. All tests were performed as described by Juul-Kristensen and colleagues.[23] The first classification system (BE) as used by Beighton and Colleagues[4] classifies JH as a score of ≥ 4. The second classification system (B) as used by Boyle and Colleagues[18] provides three sub-categories: 0-2 = (not hypermobile, NH); 3-4 = (moderately hypermobile, MH); 5-9 = (distinctly hypermobile, DH) and has a percentage agreement (81%) and spearman rho for intra-rater reliability (0.81) and interrater reliability (89% and 0.75) for these sub-category scores.[18] The third classification system (SB) as described by Stewart and Burden[8] provided three sub-categories: 0-3 = (tight, NH); 4-6 = (hypermobile, (H)) and 7-9 = (distinctly hypermobile, DH). The term 'tight' was used to define individuals who had non-lax ligaments[8] however the current study prefers to utilise the term NH for this category so as to be consistent in terminology. Three classification systems were used to allow a comprehensive comparison as the BE does allow further sub-categorisation of JH.

Intra-rater reliability was assessed by the Chartered Physiotherapist by measuring JH using the BS of 20 subjects not involved in the study on 2 separate occasions 24 hours apart. The Chartered Physiotherapist was blinded to previous results to allow determination of ICC's $(_{3,1})$.[24] Subjects were instructed not to participate in sport, dance activity or warm up during this 24 hour period. This timescale was selected to reduce the potential for ROM adaptations. Intra-rater reliability for the total BS had an ICC of 0.992 (95% Confidence Intervals 0.979-0.997) indicating excellent reliability.

Statistical analysis

Absolute scores and percentages were calculated for JH and for the contribution of each joint to JH. Hypermobility was defined as absent (0) or present (1) at each joint and a Pearsons Chi Square x^2 was used to analyse observed and expected frequencies at each joint across the six groups and contingency tables created. Analysis included all groups, male against females and female dancers against all other subgroups. Observed and expected frequencies were calculated for each group and standardised residuals were utilised providing Z scores which were classified as +/- 1.96 to +/- 2.57 ($P < 0.05$), +/- 2.58 to +/- 3.28 ($P < 0.01$) and ≥ +/- 3.29 ($P < 0.001$).[25] Cramers V was used to calculate effect size with effects sizes graded as 0.1(Small), 0.3(Medium), 0.5(Large).[26] Significance was accepted at $P < 0.05$ and all statistical analysis was performed using SPSS version 23 software (IBM Inc.)

RESULTS

The demographics of subjects were as follows: 65 FR, (65 white Caucasian, age: 20.89 $\pm$ 1.91 years, height: 164.94 $\pm$ 9.13 cm, mass: 71.76 $\pm$ 17.67 kg), 38 MR, (36 white Caucasian, 2 black Caribbean, age: 21.03 $\pm$ 2.1 years, height: 181.79 $\pm$ 6.29 cm, mass: 87.60 kg $\pm$ 12.78 kg), 61 NP (61 white Caucasian, age: 20.18 $\pm$ 1.2 years, height: 168.80 $\pm$ 7.71 cm, mass: 65.34 $\pm$ 10.57 kg), 42 FD (41 white Caucasian, 1 Hispanic, age: 20.01 $\pm$ 1.03 years, height: 162.74 $\pm$ 7.20 cm, mass: 58.77 $\pm$ 5.29 kg), 40 MS (39 white Caucasian, 1 Asian age: 20.15 $\pm$ 1.43 years, height: 176.38 $\pm$ 7.64 cm, mass: 77.98 $\pm$ 9.81 kg), and 40 FS (39 white Caucasian, 1 black African, age: 20.23 $\pm$ 1.11 years, height: 164.5 $\pm$ 7.92 cm, mass: 63.78 $\pm$ 9.92 kg).

Table 1 summarizes the frequency of JH by joint location (percentage of group value) of the six participant groups.

Table 2 summarizes BS as a percentage of group value within each category of classification when the flexion component of the BS is included and then removed (value in brackets) across the six participant groups.

Table 1. *Frequency of joint hypermobility by joint location for all subjects.*

Joint	FR (%)	MR (%)	NP (%)	FD (%)	MS (%)	FS (%)
LF	49	26	62	86	23	33
RF	38	26	49	83	18	23
LT	28	24	41	65	18	53
RT	32	18	37	50	8	40
LE	31	11	18	40	15	35
RE	20	11	26	57	8	30
LFL	43	8	41	93	15	20
LK	12	3	7	21	8	18
RK	11	3	7	24	5	10

FR; Female Rugby Players, MR; Male Rugby Players, NP; Netball Players, FD; Female Dancers, MS; Male Subjects, FS; Female Subjects; LF; Left 5th metacarpophalangeal joint, RF; Right 5th metacarpophalangeal joint, LT; Left Thumb, RT; Right Thumb, LE; Left Elbow, RE; Right Elbow, LFL; Lumbar Flexion, LK; Left Knee, RK; Right Knee

Table 2. *Beighton score and joint hypermobility classification for all subjects using the three different classification systems with lumbar flexion removed.*

CS	FR (%)	MR (%)	NP (%)	FD (%)	MS (%)	FS (%)
Be (0-3) NH	72 (75)	92 (92)	67 (69)	12 (17)	93 (95)	68 (68)
Be (≥4) H	28 (25)	8 (8)	33 (31)	88 (83)	8 (5)	33 (33)
B (0-2) NH	57 (65)	87 (87)	48 (57)	5 (13)	85 (85)	48 (55)
B (3-4) MH	22 (23)	11 (11)	28 (28)	14 (48)	13 (13)	28 (28)
B (5-9) DH	22 (15)	3 (3)	25 (15)	81 (40)	3 (3)	25 (18)
SB (0-3) NH	72 (75)	92 (92)	67 (69)	12 (17)	93 (95)	68 (68)
SB (4-6) H	20 (23)	5 (5)	26 (31)	67 (79)	5 (5)	30 (33)
SB (7-9) DH	8 (2)	3 (3)	7 (7)	21 (5)	3 (3)	3 (0)

CS; Classification System, FR; Female Rugby Players, MR; Male Rugby Players, NP; Netball Players, FD; Female Dancers, MS; Male Subjects, FS; Female Subjects, NH; Not Hypermobile, H; Hypermobile; MH; Moderately Hypermobile; DH; Distinctly Hypermobile; BE; Beighton, B; Boyle, SB; Stewart and Burden

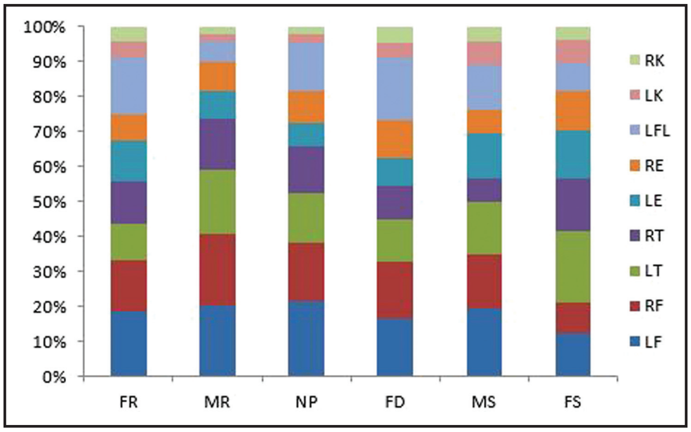

Figure 1. *The percentage contribution of positive joint hypermobility at each joint for all subjects.*
FR; Female Rugby Players, MR; Male Rugby Players, NP; Netball Players, FD; Female Dancers, MS; Male Subject, FS; Female Subjects, LF; Left 5th metacarpophalangeal joint, RF; Right 5th metacarpophalangeal joint, LT; Left Thumb, RT; Right Thumb, LE; Left Elbow, RE; Right Elbow, LFL; Lumbar Flexion, LK; Left Knee, RK; Right Knee

Figure 1 displays the percentage contribution of JH by joint location for the six participant groups.

Table 3 reports Chi square, Z and Cramer V probability scores for JH across the six groups. Group analysis of the joints revealed significant differences ($p < 0.001$) at the left and right 5th metacarpophalangeal joints, left and right thumb joints for all groups with female dancers and male controls Z scores significant at these joints. At the left and right elbow and lumbar joints significant differences existed for all groups ($p < 0.001$) with female dancers, male rugby and male control Z scores significant at these joints. At the right knee significant differences existed for all groups ($p = 0.020$) and female dancers Z scores were significant. Large effect sizes (0.541) existed for lumbar flexion.

Table 4 reports Chi square, Z and Cramer V probability scores for JH as a comparison between male and female subjects. Male subjects demonstrated significant Z scores for left and right 5th metacarpophalangeal joints, left and right thumb, left elbow and lumbar flexion. A medium effect size (0.331) existed for lumbar flexion. Comparison of male and female subjects revealed significant findings ($p < 0.001$) for left and right 5th metacarpophalangeal joints, left and right thumb, left and right elbow and lumbar flexion and at the ($p < 0.05$) level for left and right knee. Cramers Values were: left metacarpophalangeal joint 0.293; right metacarpophalangeal joint 0.234; left thumb 0.210; right thumb 0.254; left elbow 0.207; right elbow 0.225; lumbar flexion 0.331; left knee 0.118; right knee 0.122.

Table 5 reports Chi square and Z scores for JH as a comparison between female dancers and each

Table 3. *Chi square, Z and Cramer V outcomes for joint hypermobility across the six groups.*

Joint	Values	Z scores
LF	X^2 53.945 DF 10 p < 0.001* CV 0.307 CV p < 0.001*	FR Z 0.0 MR Z -1.9 NP Z 1.6 FD Z 3.5‡ MS Z -2.3** FS Z 1.4
RF	X^2 51.304 DF 5 p < 0.001* CV 0.424 CV p < 0.001*	RF Z -0.3 MR Z -1.4 NP Z 1.1 FD Z 4.4‡ MS Z -2.3** FS Z -1.8
LT	X^2 29.629 DF 5 p < 0.001* CV 0.322 CV p < 0.001*	FR Z -1.3 MR Z -1.4 NP Z 0.5 FD Z 2.8§ MS Z -2.1** FS Z 1.6
RT	X^2 23.131 DF 5 p < 0.001* CV 0.284 CV p < 0.001*	FR Z 0 MR Z -1.5 NP Z 1 FD Z 2** MS Z -2.8§ FS Z 0.9
LE	X^2 30.139 DF 5 p < 0.001* CV 0.325 CV p < 0.001*	FR Z 0.4 MR Z -2.0** NP Z -1.2 FD Z 3.6‡ MS Z -1.6 FS Z 0.8
RE	X^2 32.215 DF 5 p < 0.001* CV 0.336 CV p < 0.001*	FR Z -0.8 MR Z -1.8 NP Z 0.2 FD Z 3.9‡ MS Z -2.2** FS Z 0.7
LFL	X^2 83.592 DF 5 p < 0.001* CV 0.541 CV p < 0.001*	FR Z 0.6 MR Z -3.0§ NP Z 0.4 FD Z 5.7‡ MS Z -2.4** FS Z -1.9
LK	X^2 10.782 DF 5 p = 0.056 CV 0.194 CV p = 0.056	FR Z 0.3 MR Z -1.6 NP Z -1.1 FD Z 2.0** MS Z -0.7 FS Z 1.2
RK	X^2 13.385 DF 5 p = 0.020† CV 0.216 CV p = 0.020†	FR Z 0.3 MR Z -1.4 NP Z -0.8 FD Z 2.9§ MS Z -1.0 FS Z 0

FR; Female Rugby Players, MR; Male Rugby Players, NP; Netball Players, FD; Female Dancers, MS; Male Subjects, FS; Female Subjects; LF; Left 5th metacarpophalangeal joint, RF; Right 5th metacarpophalangeal joint, LT; Left Thumb, RT; Right Thumb, LE; Left Elbow, RE; Right Elbow, LFL; Lumbar Flexion, LK; Left Knee, RK; Right Knee

X^2; Chi Square, DF; Degrees of freedom, Z; Z score, CV; Cramers Value, CV P; Cramers Value Probability;

*= p < 0.001**,** †p < 0.005**, ‡=** p < 0.001 for Z score**, §=** p < 0.01 for Z score**, ****= p < 0.05 for Z score

Table 4. *Chi square, Z and Cramer V probability outcomes for joint hypermobility a comparison between male and female participants.*

Joint	Male	Female
LF	X^2 24.616 (DF 2) p < 0.001* Z -3.0‡ CV p < 0.001*	X^2 24.616 (DF 2) p < 0.001* Z 1.8 CV p < 0.001*
RF	X^2 15.664 (DF 1) p < 0.001* Z -2.6‡ CV p < 0.001*	X^2 15.664 (DF 1) p < 0.001* Z 1.6 CV p < 0.001*
LT	X^2 12.594 (DF 1) p < 0.001* Z -2.4§ CV p < 0.001*	X^2 12.594 (DF 1) p < 0.001* Z 1.5 CV p < 0.001*
RT	X^2 18.398 (DF 1) p < 0.001* Z -3.0‡ CV p < 0.001*	X^2 18.398 (DF 1) Pp< 0.001* Z 1.8 CV p < 0.001*
LE	X^2 12.220 (DF 1) p < 0.001* Z -2.5§ CV p < 0.001*	X^2 12.220 (DF 1) p < 0.001* Z 1.5 CV p < 0.001*
RE	X^2 14.439 (DF 1) p < 0.001* Z 1.7 CV p < 0.001*	X^2 14.439 (DF 1) p < 0.001* Z -1 CV p < 0.001*
LFL	X^2 31.382 (DF 1) p < 0.001* Z 2.3§ CV p < 0.001*	X^2 31.382 (DF 1) p < 0.001* Z -1.8 CV p < 0.001*
LK	X^2 3.964 (DF 1) p = 0.046† Z 1 CV p = 0.046†	X^2 3.964 (DF 1) p = 0.046† Z -0.3 CV p = 0.046†
RK	X^2 4.291 (DF 1) p = 0.038† Z 1 CV p = 0.038†	X^2 4.291 (DF 1 p = 0.038† Z -0.3 CV p = 0.038†

LF; Left 5th metacarpophalangeal joint, RF; Right 5th metacarpophalangeal joint, LT; Left Thumb, RT; Right Thumb, LE; Left Elbow, RE; Right Elbow, LFL; Lumbar Flexion, LK; Left Knee, RK; Right Knee

X^2; Chi Square, DF; Degrees of freedom, Z; Z score, CV P; Cramers Value Probability; *= p < 0.001, †= p < 0.005, **‡=** p < 0.01 for Z score, **§=** P < 0.05for Z score

subgroup. Significant differences existed between female dancers and all groups for left and right metacarpophalangeal joints (p < 0.001, left and right elbow (p < 0.001 to p = 0.044) and lumbar flexion (p < 0.001).

Table 6 reports Cramer V probability scores for JH as a comparison between female dancers and each subgroup. Significant differences existed between female dancers and all groups for left (p < 0.001 to p = 0.009) and right metacarpophalangeal joints (p < 0.001), left (p < 0.001 to p = 0.044) and right elbow (p < 0.001 to p = 0.023) and lumbar flexion (p < 0.001).

DISCUSSION

The aim of this study was to compare the relative joint contributions to JH scores across gender, sports and dance participation. The knee joint demonstrated the lowest JH across all populations and ranged from 3% (male rugby) to 24% (female dancers). Within male subgroups, 9% of knees were hypermobile in comparison to 25% in females in agreement

Table 5. *Chi square and Z scores for joint hypermobility: a comparison between female dancers and other groups.*

Joint	FD & FR	FD & MR	FD & NP	FD & MS	FD & FS
LF	X^2 15.757 (DF 1) p < 0.001* FR Z -1.5 FD Z 1.9	X^2 28.803 (DF 1) p < 0.001* MR Z -2.5‡ FD Z 2.4‡	X^2 6.744 (DF 1) p = 0.009† NP Z -0.9 FD Z 1.1	X^2 33.063 (DF 1) p < 0.001* MS Z -2.8§ FD Z 2‡	X^2 24.125 (DF 1) p < 0.001* FS Z -2.2‡ FD Z 2.2‡
RF	X^2 20.857 (DF 1) p < 0.001* FR Z -1.9 FD Z 2.4‡	X^2 26.355 (DF 1) p < 0.001* MR Z -2.5‡ FD Z 2.3‡	X^2 12.462 (DF 1) p < 0.001* NP Z -1.4 FD Z 1.7	X^2 35.539 (DF 1) p < 0.001* MS Z -3§ FD Z 2.9§	X^2 30.491 (DF 1) p < 0.001* FS Z -2.7§ FD Z 2.6§
LT	X^2 14.020 (DF 1) p < 0.001* FR Z -1.8 FD Z 2.2‡	X^2 13.288 (DF 1) p < 0.001* MR Z -2‡ FD Z 1.9	X^2 5.403 (DF 1) p = 0.020† NP Z -1 FD Z 1.3	X^2 18.477 (DF 1) p < 0.001* MS Z -2.4‡ FD Z 2.3‡	X^2 1.173 (DF 1) p = 0.279 FS Z -0.5 FD Z 0.5
RT	X^2 3.349 (DF 1) p = 0.067 FR Z -0.9 FD Z 1.1	X^2 8.745 (DF 1) p = 0.003† MR Z -1.7 FD Z 1.6	X^2 1.148 (DF 1) p = 0.284 NP Z -0.5 FD Z 0.6	X^2 17.876 (DF 1) p < 0.001* MS Z -2.5‡ FD Z 2.5‡	X^2 0.827 (DF 1) p = 0.363 FS Z -0.5 FD Z 0.5
LE	X^2 7.330 (DF 1) p = 0.007† FR Z -1.3 FD Z 1.6	X^2 19.056 (DF 1) p < 0.001* MR Z -2.6§ FD Z 2.4‡	X^2 15.361 (DF 1) p < 0.001* NP Z -2‡ FR Z 2.4‡	X^2 15.684 (DF 1) p < 0.001* MS Z -2.3‡ FD Z 2.2‡	X^2 4.040 (DF 1) p = 0.044† FS Z -1.1 FS Z 1
RE	X^2 13.810 (DF 1) p < 0.001* FR Z -1.9 FD Z 2.4‡	X^2 17.459 (DF 1) p < 0.001* MR Z -2.5‡ FD Z 2.3‡	X^2 8.607 (DF 1) p = 0.003† NP Z -1.5 FR Z 1.8	X^2 21.134 (DF 1) p < 0.001* MS Z -2.7§ FD Z 2.7§	X^2 5.135 (DF 1) p = 0.023† FS Z -1.2 FD Z 1.2
LFL	X^2 27.010 (DF 1) p < 0.001* FR Z -2‡ FD Z 2.5‡	X^2 57.749 (DF 1) p < 0.001* MR Z -3.8** FD Z 3.6**	X^2 28.449 (DF 1) p < 0.001* NP Z -2.1‡ FR Z 2.5‡	X^2 50.154 (DF 1) p < 0.001* MS Z -3.4** FD Z 3.3**	X^2 44.453 (DF 1) p < 0.001* FS Z -3.1§ FD Z 3§
LK	X^2 1.588 (DF 1) p = 0.208 FR Z -0.7 FD Z 0.9	X^2 6.445 (DF 1) p = 0.11 MR Z -1.7 FD Z 1.6	X^2 4.988 (DF 1) p = 0.026† NP Z -1.3 FR Z 1.6	X^2 3.182 (DF 1) p = 0.074 MS Z –1.2 FD Z 1.2	X^2 0.201 (DF 1) p = 0.654 FS Z -0.3 FD Z 0.3
RK	X^2 3.247 (DF 1) p = 0.072 FR Z -1 FD Z 1.3	X^2 7.545 (DF 1) p = 0.006† MR Z -1.8 FD Z 1.8	X^2 6.304 (DF 1) p = 0.012† NP Z -1.5 FR Z 1.8	X^2 5.802 (DF 1) p = 0.016† MS Z -1.6 FD Z 1.6	X^2 2.760 (DF 1) p = 0.097 FS Z -1.1 FD Z -1.1

FR; Female Rugby Players, MR; Male Rugby Players, NP; Netball Players, FD; Female Dancers, MS; Male Subjects, FS; Female Subjects; LF; Left 5th metacarpophalangeal joint, RF; Right 5th metacarpophalangeal joint, LT; Left Thumb, RT; Right Thumb, LE; Left Elbow, RE; Right Elbow, LFL; Lumbar Flexion, LK; Left Knee, RK; Right Knee

X^2; Chi Square, DF; Degrees of Freedom, Z; Z score; *= Significant p-value < 0.001, †=Significant p-value, **‡=** p < 0.05 for Z score, **§=** p < 0.01for Z score, ****=** p < 0.001 for Z score

with previous findings of increased knee joint laxity in females.[27] As left and right knee are the only measurements of hypermobility performed in the lower limb there may be a need to measure other joints such as the ankle or toes to provide a more specific measure of body joint hypermobility. This may have particular importance in dance which requires movements such as "en pointe" which increase the stress on these joints. Within netball players the high prevalence of 5th metacarpophalangeal JH in comparison to female rugby players and female controls may represent a sporting adaptation. This is in contrast to previous research in elite netballers that found this to be the least hypermobile joint.[10] and may reflect the different levels of netballer.

Lumbar flexion demonstrated significant x^2 values and large effect sizes for all groups however this effect size was reduced to a medium effect size when male against female analysis was performed. This highlights the need for the careful consideration of inclusion of this measurement in determining JH. Particular caution is required with female dancers with this study demonstrating a lumbar flexion JH rate of 93% for this cohort. Lumbar forward flexion is acquired through dance training[13] and lumbar

Table 6. *Cramer V outcomes for joint hypermobility: a comparison between female dancers and other groups.*

Joint	FD & FR	FD & MR	FD & NP	FD & MS	FD & FS
LF	CV 0.384 CV p < 0.001*	CV 0.660 CV p < 0.001*	CV 0.256 CV p = 0.009†	CV 0.635 CV p < 0.001*	CV 0.542 CV p < 0.001*
RF	CV 0.441 CV p < 0.001*	CV 0.574 CV p < 0.001*	CV 0.348 CV p < 0.001*	CV 0.658 CV p < 0.001*	CV 0.610 CV p < 0.001*
LT	CV 0.362 CV p < 0.001*	CV 0.408 CV p < 0.001*	CV 0.229 CV p = 0.020†	CV 0.475 CV p < 0.001*	CV 0.120 CV p = 0.279
RT	CV 0.177 CV p = 0.067	CV 0.331 CV p = 0.003†	CV 0.106 CV p = 0.284	CV 0.467 CV p < 0.001*	CV 0.100 CV p = 0.363
LE	CV 0.262 CV p = 0.007†	CV 0.488 CV p < 0.001*	CV 0.386 CV p < 0.001*	CV 0.437 CV p < 0.001*	CV 0.222 CV p = 0.044†
RE	CV 0.359 CV p < 0.001*	CV 0.467 CV p < 0.001*	CV 0.289 CV p = 0.003†	CV 0.508 CV p < 0.001*	CV 0.250 CV p = 0.023†
LFL	CV 0.502 CV p < 0.001*	CV 0.85 CV p < 0.001*	CV 0.526 CV p < 0.001*	CV 0.782 CV p < 0.001*	CV 0.736 CV p < 0.001*
LK	CV 0.122 CV p = 0.208	CV 0.284 CV p = 0.11	CV 0.220 CV p = 0.026†	CV 0.197 CV p = 0.074	CV 0.050 CV p = 0.654
RK	CV 0.174 CV p = 0.208	CV 0.307 CV p = 0.006†	CV 0.247 CV p = 0.012†	CV 0.266 CV p = 0.016†	CV 0.183 CV p = 0.097

FR; Female Rugby Players, MR; Male Rugby Players, NP; Netball Players, FD; Female Dancers, MS; Male Subjects, FS; Female Subjects; LF; Left 5th metacarpophalangeal joint, RF; Right 5th metacarpophalangeal joint, LT; Left Thumb, RT; Right Thumb, LE; Left Elbow, RE; Right Elbow, LFL; Lumbar Flexion, LK; Left Knee, RK; Right Knee, CV; Cramers Value, CV P; Cramers Value Probability

*= p < 0.001, †=Significant p- value

flexion JH rates of 91.5% in 47 dancers and a rate of 6.4% have been reported in age and gender matched controls.[14] In the current study, 88% (n = 37) female dancers were hypermobile, in contrast previous literature reported JH rates of 66% (n = 24, BS ≥ 4) in professional female dancers[11] and only 4.3% (n = 2, BS ≥ 4)[14] in professional ballet dancers however in this study 36% of participants were male. After female dancers the highest prevalence of lumbar flexion JH was female rugby players 43% (n = 28), netball players 41% (n = 25), female controls 20% (n = 8), male controls 15% (n = 6) and male rugby players 8% (n = 3) highlighting a gender difference. At the upper limb joints and on lumbar flexion male subgroups demonstrated reduced hypermobility levels to expected X^2 values.

In relation to the number of subjects with JH the removal of lumbar flexion from the three hypermobility classifications resulted in no change in "not hypermobile" (NH) scores across the three classifications in male rugby and an increase of 5% (n = 2) in male controls (BE and SB). In netball players, the B classification (0-2) increased by 9.8% (n = 6) in comparison to the BS and BE classification increase of 1.6% (n = 1) while female rugby remained similar at 3% (n = 2) (BE and SB) and 8% (n = 5) (B). Female dancers demonstrated large changes in the B classification 'moderately hypermobile" (MH) (3-4) with an increase of 33.3% (n = 14) in contrast to a decrease -4.8% (n = -2) and increase of 11.9% (n = 5) respectively in the BE (≥4) and SB "hypermobile" (4-6) classifications. This highlights classification system variation and influence of lumbar flexion inclusion. The other populations demonstrated smaller changes ranging from an increase of 4.9% (n = 3) in netball players SB (4-6) "hypermobile" to no change in male subgroups across all classifications. Within the categorisation of B "distinctly hypermobile" (DH) (5-9) and SB DH (7-9) there were no changes in male subgroups. In females changes occurred in all groups with female dancers demonstrating noticeable differences across the classifications with a decrease of -40.1% (n = -17) in the B classification and a decrease of -16.7% (n = -7) in SB classification. The removal of lumbar flexion from total BS had no effect on JH prevalence in male subgroups in contrast to females and therefore there may be a need to consider this in JH interpretation. Other female subgroups demonstrated smaller reductions within the two classifications.

Within dance the generally untrained joints of the 5th metacarpophalangeal, thumbs and elbows may provide an indication of general JH and are unlikely to have been exposed to the potential performance adaptation associated with lumbar flexion. Female dancers had the lowest percentage JH contribution (73%) from these three joints which may demonstrate a performance related adaptation that results in lumbar flexion and the knee joint contributing more. In both male subgroups lumbar flexion was restricted in comparison to females which may be related to poor hamstring flexibility which can influence this measurement. The finger tips to floor test which involves the same movement has been shown to be a reliable measure of hamstring flexibility.[28] This involves contribution of the hip, wrist, fingers, elbows and shoulders and therefore is not an isolated joint movement like the other measurements. Such functional movements may require different interpretation within the BS. There may be a need for interpretation of the lumbar flexion movement to be combined with performance of a Schöbers or Schöbers modified test[29] to determine the contribution of the lumbar spine. The Schöbers test involves palpating and marking the lumbosacral junction and then marking another point 10cm superiorly and asking participants to flex as far forwards as possible while ensuring the knees remain fully extended and the distance between the two points is measured.[30] The modified version uses the same movement and marks and requires the addition of a mark 5cm below the lumbrosacral junction and the distance between this mark and the mark made 10cm above lumbrosacral junction is measured with participant in a flexed position.[30] Test retest reliability of these two methods has been reported as r = 0.87 indicating excellent reliabity.[30] A straight leg raise test[31] could be used to determine hamstring ROM contribution more effectively.

The comparison between female dancers and other subgroups revealed significant findings between female dancers and female rugby players and medium to large effects sizes existed for all joints except the right thumb and both knees. Female dancers and netball players analysis was significant at all joints except the right thumb and medium effect sizes existed at the right 5th metacarpophalangeal and left elbow joints. Female dancers and female control analysis revealed significant findings at all joints except at both thumbs and knees and large effect sizes at both 5th metacarpophalangeal joints and the lumbar spine. Female dancers and male rugby players analysis revealed significant findings and medium to large effect sizes at all joint except the left knee. Analysis of female dancers and male controls revealed significant differences at all joints except the left knee and medium to large effect sizes existed at all joints except the knee. At the left and right knee differences between groups and gender were less prominent with only female dancers demonstrating significant findings. At all joint locations, JH was higher in females than males supporting the greater prevalence of female JH[7] and therefore females may need to be categorised differently. Although the purpose of this study was not to compare total JH scores it must be acknowledged that with all three classification systems the prevalence of JH was greatest in female dancers even with lumbar flexion removed and the values were greater than those previously reported.[11]

JH classification in rugby union, netball and dance via three different classifications systems suggests that the consideration of gender, sport and dance participation is important in determining normal vales and there is a need to consider age, gender and ethnicity.[32] The current findings have clinical importance as decisions regarding injury prevention, training load and sport selection based on the BS should consider carefully joint contribution to JH scores. Gender and predominant activity of the individual is important and should be compared with expected values within the domain and the potential contribution to injury risk or performance variation should be considered. Currently the interpretation of total JH score may not be the best practice due to gender and sport variations in lumbar flexion JH, knee JH and the contribution of upper limb to total JH score. The findings may demonstrate a continuum of hypermobility which may demonstrate either a performance adaptation or selection bias highlighted by the differences between male and female subgroups with female dancers and netball players demonstrating greater hypermobility than female rugby players. The initial implementation of the BS was as an epidemiological tool and not as a sport or dance specific tool and therefore the development of sport or dance specific grading scales seems a logical progression.

The results of the study are limited to the populations investigated and the classification systems used do not report specific joint ROM. Further studies should consider male dancers, report joint ROM and utilize a larger sample size. It appears that further investigation of increased female JH at the knee joint is required as well as additional reports on the prevalence of 5th finger metacarpophalangeal hypermobility in netball players. Long term studies that potentially measure changes in JH with relation to participation in varied sports or dance performance may allow determination of potential long-term performance adaptations. Future research assessing JH of female dancer may benefit from providing two scores which include and exclude lumbar flexion as female dancers may have a different normal range for this measurement.

CONCLUSION

Females and males are subject to differences in the relative contribution to JH and the functional nature of lumbar flexion may require different interpretation within the BS. Within female dancers, a positive lumbar flexion JH score may be a sign of performance adaptation rather than a measure of JH and therefore its inclusion within JH grading within this group requires careful consideration.

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